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THE

Longitude *and* Latitude

Found by the

INCLINATORY

OR

DIPPING NEEDLE

Wiston (W)



[3]

The LONGITUDE and LATITUDE found by the INCLINATORY or DIPPING NEEDLE.

D E F I N I T I O N



AN Inclinary or Dipping Needle, is a long and strait piece of Steel, every way equally pois'd upon its Center, and afterwards touch'd with a Loadstone; but so contriv'd, as not to play on the Point of a Pin, as does the common Horizontal Needle; but to Swing in a Vertical Plain, about an Axis, parallel to the Horizon; and this in order to discover the exact Tendency of the Power of Magnetism.

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OBSERVATIONS.

I. The true Tendency of the *North* or *South* End of every Magnetick Needle, is not at all towards that Place in the Horizon whither the Horizontal Needle points, but towards another directly under it, in the same Vertical; and in different Degrees under it, in different Ages and Countries. *Ex. Gr.* At *London* this Tendency is now of the *North* End of the Needle, about $73^{\circ} 45'$ below the Horizon. Whereas *A. D.* 1576, when this Property was first discovered, it was about $71^{\circ} 50'$, as *Mr. Norman* assures us, in his *New Attractive*; which I have added at the End of this Paper.

This Observation is also manifest in all Tryals of common Magnetick Needles; which though exactly pois'd in an Horizontal Position, before they are touch'd with the Loadstone; do yet, after that Touch, tend towards this Direction: And when contriv'd so as to Swing in that Vertical Plain, will never rest in any other Position, without some other Force to counterbalance that Tendency. And indeed, by this Alteration of the Equilibrium of Horizontal Needles, upon the Touch, it was, that *Mr. Norman*, at *Wapping*,

ping, first discovered and made the Dipping Needle; in or about A. D. 1576, as himself informs us in his forementioned *New Attractive*.

II. This Line of the Needle's Tendency is therefore to be considered, when we treat of the Power of Magnetism, in the very same Manner as is the Line of Direction towards the Earth's Center, when we treat of the Power of Gravity. This Magnetick Power appearing to be equally constant and uniform in this Direction, as is the Power of Gravity in the other.

III. The Angle of Dip, or Inclination below the Horizon, is then only the true one, or the least of all; and the Angle of the Needle from the Nadir the greatest; when the Plain of the Needle's Oscillations is directly along the Magnetick Meridian, or when the Intersection of the Plain with the Horizon is the true Variation of the Needle in that Place.

IV. When that Plain is at right Angles with the former, or in the Magnetick *East* and *West*, this Angle of Dip or Inclination is a right Angle; and the Needle does not at all ascend from the Nadir.

Corol-

Corollary. When therefore the Dipping Needle stands exactly Perpendicular to the Horizon, the Intersection of that Plain with the Horizon, makes an Angle with the true East and West Line, equal to the Variation of the Needle at that Place.

N. B. Because, as we shall see hereafter, the Alteration of the Ascent of the Needle is according to the Degrees on the Line of Sines; which at first differ very much; but at last exceeding little; this Angle of the Variation is discover'd best by the Dipping Needle, in this Position of its Plain, and not in that along the Magnetick Meridian.

N. B. If the Plain of the Needle therefore, be but within Three, Four, or even Five Degrees of the Magnetick Meridian, the Angle of Inclination will be almost as exact as if it were perfectly along that Line. The Reason is obvious: For the Sine of 85° differing from that of 90° not quite the 250th Part of the Radius; this Difference can hardly ever come to more than one Third of a Degree, or $20'$, and with us never comes to more than $4'$. And the Sine of $87^{\circ}\frac{1}{2}$ differing from that of 90° , not quite the 1000th Part of the Radius, or but one Quarter of the former Difference, this Error can hardly ever come to more than $5'$, and with us never comes to
more

more than 1. Which Thing is of great Advantage for Practice, in finding the true Angle of Inclination with Dipping Needles: Though it has not indeed any Place in the finding the Angle equal to the Variation; which admits of no such Allowance for Inaccuracy as is here mentioned.

V. The greatest Exactness that is necessary in the Situation of the Dipping Needle is, that its Plain be exactly Vertical, or Perpendicular to the Horizon: And a very small Error in this Case will occasion a very great one in the Angle of Inclination; nay, will cause such a Disorder, that one Side of the Instrument will shew a considerably different Angle from the other: Which otherwise does not happen.

N. B. Some of the Experiments made with Dipping Needles, have been quite spoiled for want of the Correction of this Error in the Situation of the Instrument; especially that otherwise very valuable Set of them, which the Reverend Mr. Pound and Mr. Cunningham made, in their Voyage to China, A. D. 1700, and which we have, from Mr. Cunningham's Journal, in our Philosophical Transactions of the Year 1704, Numb. 292, where the Difference on the Two Sides after it was

was observ'd, arose sometimes to 12° or 13° , and how high it had gone before, we do not know. And the like Error in my Dipping Needles, was one of the last and most perplexing Difficulties which lay upon me in my own Tryals; will I was so happy to observe, that it nearly arose from the inaccurate Position of the Plain of my Instrument, while it was not exactly Perpendicular to the Horizon. And Note farther, That wherever this Exactness of the Plain of the Needle cannot be quite obtain'd, without too much Trouble, the Observer must look on the Needle, the Plain being turn'd first on one Side, and then on the other; And if it differs but a Degree, or less, he may safely take the mean Dip between both for the true one: Which in such a Case will be in a manner as accurate, as if he had, with much more Pains, prevented that small Inequality. But if this Difference be much more than a whole Degree, it will not be safe for us to trust to such a middle Number, if we pretend to Exactness in our Observations.

P R O.

PROPOSITIONS.

I. A Pendulum, whose Center of Suspension is distant from the Center of Oscillation 39²/₂ Inches makes every Swing in the least Arc of a Circle in one Second, or 60⁰.

This is well known by all that make long Pendulum Clocks; or have try'd Experiments with other Pendulous Bodies.

N. B. I say here, every Swing, in the least Arc only: for so is the Fact. In Cycloids indeed, the Swings or Oscillations are all exactly equal, be the Arcs never so unequal: But in Circles they are not so. The larger Arcs requiring still a longer Time than the shorter, and the Quadrantal Arc requiring so much more Time than the smallest, as 34 is more than 29; which the famous Monsieur *Huygens* has demonstrated.

II. A Pendulum Four Inches long, describes very small Arcs in a little less than one Third Part of a Second, or exactly in 19²/₂.

B

This

This is easily found, by extracting the Square Roots of the former Numbers, 39.2, and 4, which are 6.27, and 2. It being well known in Mechanics, that the Lengths of Pendulums are as the Squares of their Times of Oscillation: Or, which is all one, that the Times are as the Square Roots of those Lengths. Whence the Analogy will run thus,

$$6.27. : 2. :: 60'' : 19.2''$$

III. A Prismatick, or Cylindrick Solid and Pendulous Body Six Inches long, swinging about one End as a Center, performs each Oscillation in the same Time with a common Pendulum or Plumbet, hung by a Thread of Four Inches; that is in 19.2''.

This is well known by the Place of the Center of Oscillation in all Cylindrick and Prismatick Bodies; which is demonstrated to be at $\frac{1}{3}$ of the whole Length: And by Experiments purposely made with Tash Bodies, which fully confirm that Demonstration.

IV. An Inclinary or Dipping Needle of Six Inches Radius, and of a Prismatick or Cylindrick Figure, when it oscillates along the Magnetick Meridian, performs here every mean Oscillation in about 6'' or 360''.

This

This is a bare Matter of Fact: And I have my self often found it to be so upon Tryal.

N. B. I use the Word *mean Oscillation* here, because in these Magnetick Oscillations, as well as those derived from Gravity, the large Arcs require longer Time than the small ones: And, I believe, in the same Proportion. So that when we compare their Velocities and Motions together, we must take Similar Oscillations, as I here take the mean ones; though possibly the Equality of the Oscillations in such Cases will, on all Sides, be secured better, by beginning with those less than 30 Degrees from the *Nadir*, where they are almost equal; than with the largest, which are more unequal.

V. The Force of Gravity, or of any uniform Power, in Plains oblique to the Direction of that Power, is always as the Cosines of the Angles made by the Direction of that Power, and the oblique Plain: And the Times in which equal Lines are described, are in the subduplicate Proportion of the same.

Thus the Power of Gravity, which it self tends only *Fig. I.* along the Perpendicular A C: to accelerate the Body O along the oblique Plain B 2

Plain A B, is ever as the Cosine A C, to the Radius A B. and the Times of the Description of equal Lines, as the Square Roots of the same.

Thus if A C be one Quarter of A B; the Force along A B, and the Line described in equal Time along A B, will be one Quarter of the Force and Line along A C. and the Times of the Description of equal Lines as 2 to 1. If A C be $\frac{1}{3}$ of A B, the Force along A B, and the Line described in equal Time along A B, will be $\frac{1}{9}$ of the Force and Line along A C, and the Times of the Description of equal Lines, as 3 to 1, and so for ever: As I have demonstrated in my *Mathematical Philosophy*; and as is now well known in Mechanics.

Corollary (1.) If therefore the same Pendulum, finely Polished, do oscillate both in a Vertical Plain, and upon a Glass Plain, inclin'd to the Horizon, the Times of each similar Oscillation, or of any equal Number of such Oscillations, will be to each other reciprocally, as the Square Roots of the Numbers expressing the Proportion of the Cosine A C, to the Radius A B. I mean this, with no greater Inequality than must arise from Friction in the oblique Glass Plain, which has no Place in the Vertical Plain. Thus when I tried the Experiment

periment with a Pendulum Four Inches long, which, as we have seen, oscillates in the Vertical Plain, in $19,2''$, yet upon a Glass Plain so inclin'd, that AC was one Quarter of AB, and where, by Consequence, had there been no Friction, the Time would have been only Double, or $38,4''$, it was somewhat longer, or above $42''$. Which however is sufficiently near to this Rule; and is accordingly a real Confirmation of it.

VI. The entire Power of Gravity, is to the entire Power of Magnetism, in this Country, nearly, as 352 to 1.

This is a plain Corollary from the Third, Fourth, and Fifth Propositions foregoing. For since equal Arcs of equal Circles, are described by these Two Powers in unequal Times, which Times are to one another, upon Tryal, as $360''$ to $19,2''$ their Squares, which are 129600, and 368, will give us the Proportion of the Powers themselves: which is the same with that of 352 to 1.

Corollary. What Things therefore are any where demonstrated of the Power of Gravity, or of any other uniform Power, will equally agree to this Power of Magnetism: Allowance being still made for the different Quantities, and

and different Directions of these Powers: Examples of which will now follow.

VII. The Quantity of Magnetick Power accelerating the same Dipping Needle, as it oscillates in different Vertical Plains, is ever as the Cosines of the Angles made by those Plains, and the Magnetick Meridian, taken upon the Horizon.

Let AI represent the greatest Force, along the Magnetick Meridian, as the Semidiameter of a Circle:
Fig. II. [A being the Point where the Dipping Needle would cut the Horizon, when it stands Perpendicular thereto, and swings along the Tangent AB : and I , being the Point where the same Needle, hanging from the same Center, would cut the Horizon in its proper Inclination, along the Magnetick Meridian.]
 Let the Angles at A be drawn at Random, or for greater Ease, as here, exceeding each other by 15 Degrees. Draw the Chords AC , AD , AE , AF , and AG . Then will Ac , Ad , Ae , Af , and Ag , be the Cosines of the Angles made by the Line of greatest Force AI ; and the several Plains, here represented by the Chords AC , AD , AE , AF , and AG . These Cosines therefore, as compar'd with the Radius AI , express the true Proportion of the Power of Magnetism in all these oblique Situations,

just

Just as A C expressed that of Gravity along AB, in Proposition V foregoing.

Corollary (1.) Since the Ascents of the Dipping Needle from the Nadir A, taken along the Circle of the Dipping Needle, must needs increase till they come nearest to the Power at I, i. e, as far as c, d, e, f, and g, which are the Length of the Cosines above-mentioned; At which nearest Points alone, the Needle can rest: 'Tis evident that these Ascents, or Complements of the Dips below the Horizon, will be still in the Proportion of those Cosines respectively.

Corollary (2.) Because the Sine of 30° is half the Radius, the Ascent of the Dipping Needle along the Line, or Plain A D, at 60° Degrees Distance from the Magnetick Meridian A I, will be one Half of the utmost Ascent; and is the most easily tried by every body.

Thus, because at London, the utmost Ascent of 8 along the Magnetick Meridian is $169 \frac{1}{2}$, the Ascent at 60° Degrees therefrom, on either Side, will be $89 \frac{1}{2}$, and so every where. Accordingly I have several times tried this Experiment, and always found it to answer the Demonstration, not in that Angle only, but in all others also.

Corol.

Corollary (3.) If the former Construction be suppos'd in a Plain Perpendicular to the Horizon, upon the same Al , as still the Semidiameter of the same Circle; and it be suppos'd to be plac'd from the Center of the Dipping Needle, along the Magnetick Direction; that so the Sines Ac , Ad , &c. may represent the oblique Forces as before: We may thence estimate the Quantity of those Forces, both in the Horizontal and Vertical Situation of Needles: The one exhibiting the Force of the Horizontal Needle; the other of the Vertical Dipping Needle, whose Plain is along the Magnetick East and West.

Corollary (2.) Because the Sine of 30° is 50 to 100 ; and the Sine of $63^\circ 47'$ is 96 to 100 ; Thus, if we would Estimate the Quantity of Force at London in the Vertical Plain here mentioned, we shall find, that it is to the entire Force along the Magnetick Meridian, as the Sine of $63^\circ 47'$ to the Sine *Totus*; or as 96 to 100 ; and by Consequence, that their Times of Oscillation are in the subduplicate Proportion of those Numbers; i. e. nearly as 98 to 100 , or 49 to 50 , which agrees to Experience.

Thus also, if we would estimate the Quantity of Force here in the Horizontal Plain, we shall find it is to the same entire

entire Force above-mentioned, as the Sine of 16° ; to the *Sinus Totus*; or as 28 to 100; and by Consequence, that the Times of their Vibrations, and Oscillations, which are in the subduplicate Proportion of those Numbers; are as 52.9 to 100, or as 11 $\frac{1}{2}$ to 6"; which also agrees to Experience.

N. B. The Power by which all Horizontal Needles are governed, and all our Navigation directed, in these Parts of the World, is not near the Third Part of the Power by which the Dipping Needle is moved, and the Longitude and Latitude of Places are now proposed to be discovered.

Corollary (A). Hence we learn a new and sure way of finding the true Angle of Inclination of the Dipping Needle, even without immediately observing it; and that by one single Analogy, thus: As the Square of the Time of any Number of Vibrations in the Horizontal Plain, to the Square of the Time of the same Number of Similar Oscillations in the Vertical Plain, along the Magnetick Meridian: So is the *Sinus Totus*, to the Cosine of the Angle of Inclination.

Let

Let us suppose that 100 of these Vibrations are to 100 Similar Oscillations, or, which is the same Thing, one Vibration to one Oscillation, as $11''\frac{1}{2}$ to $6''$; or that the same Needle, when playing Horizontally, takes up $11''\frac{1}{2}$ in one Vibration; and when playing Vertically takes up but $6''$; Then will the Analogy run thus: $11''\frac{1}{2}q: 6''q:: 128: 36:: 100 = \text{Rad}: 28 = \text{Sin}. 16^\circ\frac{1}{2}$

N. B. Where the Angle of Inclination is less than 45° , it will be best to find its Complement; the Angle of Ascent, by comparing the Oscillations along the Magnetick *East* and *West*, with those along the Magnetick Meridian: Which will be done by the foregoing Analogy.

N. B. If the Power of Magnetism were as nearly the same every where on the Earth's Surface, as is that of Gravity, the forementioned Angles might be found by the Horizontal Needle alone, from the same Analogy. The First and Third Terms in that Case being standing Quantities; and there being Occasion for nothing but counting the Number of Seconds in an equal Number of Vibrations of the Horizontal Needle. However, this

this Method by Calculation ought every where to be put in Practice, together with the direct Observation of the Dip it self; that so the Angle may be confirm'd, or, on any Error happening therein, corrected, for the greater Security of Navigation.

VIII. Dipping Needles of different Lengths have their Times of Vibration, and Angular Velocities, in a subduplicate Proportion of their Lengths *Reciprocally*. They have also their real Velocities along their Arcs in that subduplicate Proportion of their Lengths *directly*.

Thus, if one Dipping Needle be Four Times as long as another, its Time of Oscillation and Angular Velocity, will be one Half of the others: And the real Velocity of its End will be Twice as great as that of the others. If one be Nine Times as long as another, its Time of Oscillation, and its Angular Velocity, will be $\frac{1}{3}$ of the others: And its real Velocity at the End, will be Three Times as great as that of the others: And so for ever.

These are known Propositions relating to Pendulous Bodies, and in all the like

Cases where any uniform Power operates on Bodies: And need not be here distinctly demonstrated of the Dipping Needle. Accordingly Experience equally attests to them in this, as in other Cases.

Corollary. The Angular Velocity of a Dipping Needle 3₅₉ Feet long, will be equal to that of an Horizontal Needle at London, one Foot long; and equally strong in its Motion. The Angular Velocity also of a Dipping Needle 12₆ Feet long, will be to that of this Horizontal Needle, as 1 to 3₅₉. whose Squares are as 793. the Cosine of $85^{\circ}. 27'$. to the Radius 10000. *i. e.* its Angular Velocity and Strength will be same as these of the Horizontal Needle of a Foot long, where the Dip is $85^{\circ}. 27'$.

Corollary (2.) Since therefore common Horizontal Needles, of a Foot long, have sufficient Strength to play, and shew the Points of the Compass, in much greater Inclinations of the Dipping Needle than that now mentioned: 'Tis clear, that Dipping Needles may be much above 12 Feet long, and yet have sufficient Strength for the Performance of their Vibrations.

Corol.

Corollary (3.) Since the Horizontal Needle is moved only by a Part of the Power which moves the Dipping Needle; and that it only points to a certain Place in the Horizon, because that Place is nearest its Original Tendency; whenever the Dipping Needle stands exactly Perpendicular to the Horizon, the Horizontal Needle will not respect one Point of the Compass more than another, but will wheel about every way uncertainly.

And wherever it happens that this Needle does so, as it has sometimes done, it is evident the Dipping Needle is there exactly Perpendicular to the Horizon: Though indeed that perfect Equilibrium, arising from such an exact Perpendicularity, can reach but to a very small Compass of Ground; and so must be a very rare Thing in Observation.

IX. A Dipping Needle of a Foot long, will plainly shew an Alteration of the Angle of Inclination, in these Parts of the World, in half a Quarter of a Degree, or $7\frac{1}{2}$ Geographical Miles; I mean this, if we go along, or near to a Meridian.

This I have found my self upon Trial, in travelling this *Autumn* from *Lincoln* to near *Oxford*; and the same, or a greater
Exact-

Exactness, appears practicable from the Observations of Mr. Norman, and Mr. Bond, when they had good Needles, and took Care to be accurate in their Observations.

N.B. If therefore this Alteration is visible in these Parts of the World, along or near a Meridian, within half a Quarter of a Degree, where yet the Dipping Needle alters not near so fast as the Latitude; or where we must go above 100 Geographical Miles, for the Difference of 75': Such an Alteration will be visible in a much less Space of Ground, in most other Parts of the World: Where 'tis not only common that the Minutes of the Dipping Needle alter as fast as the Geographical Miles of Latitude, but that, in the Torrid Zone especially, those Minutes alter much faster than the other; and where, upon the whole, taking one Place with another, the Dipping Needle affords an Alteration of about 180° , while we Travel 140 Miles along a Meridian, as the Observations already made do assure us.

Corollary. Hence it is plain, that the Latitude may generally be discovered by the Dipping Needle, though it be no more than a Foot long, when we Travel along or near a Meridian, more nicely than to 7½ Miles, and that

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it may be discovered by one of Four Foot; nearer than 2 Miles; that is, much nearer than it is now usually known at Sea by Celestial Observations.

X. A Dipping Needle of Four Foot long, in these Parts of the World, will shew an equal Alteration along a Parallel, that one of a Foot long will shew along a Meridian: That is, This will with equal Exactness shew the Longitude, as That the Latitude, both by Sea and Land.

This depends upon the Position of the *Lines of equal Dip*, in these Parts of the World, which are found, upon Tryal, to lie about 14 or 15 Degrees from the Parallels: Or where the intercepted Parts along a Meridian, are about one quarter of those along Parallels: As the View of my Map hereto belonging, which is made from the best Observations, will readily demonstrate.

Corollary (1.) Since therefore we can observe an Alteration in the Dipping Needle of one Foot long, when we go nearly North and South, in 7 $\frac{1}{2}$ Geographical Miles Space, we can do the same with one of Four Feet, when we go East or West: i. e. We can by such a Needle discover our Longitude to half a quar-

a quarter of a Degree, or 7½ Miles, even here, and much nearer in other Parts of the World.

Corollary (2.) Since, as we have shewn, we can have Needles not only of 4, but of 8, or 12 Feet long; which will move with Strength sufficient for good Observations. And since, by the Use of Microscopes, in viewing the small Divisions of Degrees on the Limb of our Instrument; we can still greatly improve the Exactness of our Observation; since also, by a Ball of Brass, or Steel, at one Side of the Center, instead of one half of the Needle, we can take away almost one half of the troublesome length of that Needle: It is evident, that it is no way impossible to discover, at Land, by a Dipping Needle, our Longitude, nearer than to Four Miles.

Corollary (3.) Since many Observations have been already made at Sea, and on Shipboard, with Dipping Needles, by Mr. Hudson, Mr. Noel, Mr. Pound, Mr. Cunningham, Monsieur Feuillée, and others; which have determined the Dip usually within a Degree; sometimes within half a Degree, or nearer; and this with small Needles of 5 or 6 Inches long: 'Tis evident, that at the same Rate, and with the like Care, we may determine this Dip, even at Sea, to much nearer than half a quarter

quarter of a Degree, and the Longitude, usually still nearer; even without any farther Improvements of the way of making such Observations there: Which yet are justly to be expected, when the Consequence of such Exactness will appear to be so very considerable.

XI. The Intervals between the Lines of equal Dip, taken in any equal Number of Degrees, as 10° , 20° , 30° , 40° , &c. are regular; and nearly, if not exactly, observe the Proportion of the Sines of such Angles: Beginning where the Dip is Perpendicular to the Horizon. The Lines themselves also of such equal Dip, approach to Parallel Circles, about the several Magnetick Poles of the Earth.

This Proposition is proved both *a Priori*, and *a Posteriori*: From the Experiment of the Situation of small Needles, and their equal Dips, upon the Surface of Spherical Loadstones; and from the Fact of the Distance and Position of such Lines upon the Surface of the Earth, found by Observation there.

As to the former Proof, *a Priori*, I have myself exactly tried it upon the strongest *Terrella*, or Spherical Loadstone now known; I mean that in the Possession of

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the Right Honourable the Lord *Piesley*:
 And have found that the Dip of the small
 end of a Needle, below its Surface or
 Horizon, is, at 22° $\frac{1}{2}$ from its Equator,
 41° $\frac{1}{2}$ Degrees: at 45° from it, 60° De-
 grees: And at 67° $\frac{1}{2}$ from it, 75° $\frac{1}{2}$ De-
 grees: While at the Equator, this small
 Needle lies along that Surface; and at
 each Pole stands perpendicular thereto.
 All which the Nature of the Line of
 Sines, and of no other Line, does ex-
 actly require. The Lines of equal Dip
 are thereon also no other than the Pa-
 rallels to the Equator; as all our Tri-
 als demonstrate; and as every body used
 to Spherical Loadstones will readily agree.

As to the latter Proof, *a Posteriori*, it is to
 to be taken, as to both Parts, from the
 Situation and Distance of these Lines of
 equal Dip, upon a Terrestrial Globe or
 Map, made from the best Observations:
 Which, in the former Case, more ex-
 actly, and in the latter pretty nearly and
 generally agree to this Proposition.

Corollary. (1.) The proportionable Distance of
 these Lines of equal Dip, and the Situation of
 these Lines along Magnetick Parallels, will be
 the most uniform and regular in Places near
 the several Poles, of internal Loadstones,
 where

where their several Powers will most strongly and distinctly exert themselves; and they will be most disorderly and irregular nearest their several Equators; especially in the Situation of these Lines, with regard to the magnetick Parallels; which will there be along a Sort of Diagonal Lines, whose Sides, in Composition of Motion, will be those very Magnetick Parallels.

Corollary (2.) Since it appears from Observation, that the several Poles of the internal Magnets are considerably distant from the Poles of the Earth, these Parallels, or Lines of equal Dip, will very rarely fall into the Parallels of the Earth's Equator: Which yet is the only possible Case, where this Method will discover no more than the Latitude.

N. B. This Coincidence with our Parallels, seems now to be between *Europe* and *America*, near 30° North Latitude: To which alone, of all the Places now frequented in Navigation, this Imperfection of our present Method appears to belong. However, as the Use of very long Dipping Needles will reduce that Space to a small Breadth, on each Side of such coincident Parallels; so will it be easy to avoid the Inconvenience arising therefrom. For since the Longitude may still be found

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along

along other Parallels at a small Distance both North and South, Pilots may easily Sail along one of those Parallels, where the Longitude can be found, till they come to the Meridian of the Place they Sail to : And then they may run along that Meridian till they arrive there. Which will be the more easily done, because the Parallel of that Place will, in this Case, be found by our Dipping Needle in the greatest Perfection. Nor will the length of this Course be considerably greater than the usual one by the Rumb Line.

Corollary (3.) Where we have several good Observations of the Angles of Inclination or Dip, at considerable Distances from each other, we may pretty nearly find the rest now, by Analogy to the Line of Sines, without waiting for other Observations. Nor will Sea Charts made from such *Data*, be wholly useless at Sea, even at present ; because the Observations to be made at some particular Places, especially as join'd to the Use of the Line of Sines, will soon enable the Pilots to correct those Lines of equal Dip, upon their Charts, and to guide themselves, in some Measure, the rest of their Voyage, by such corrected Lines also. Though it must be confess'd, that such Charts cannot but require many more, and much nicer Observations, than we yet have, in order to their utmost Perfection.

N. B. Since

N. B. Since the Quantity of the Inclination of the Dipping Needle has varied here at *London*, [the only Place in the World where it has been long enough known to determine that Variation,] scarce Two Degrees in 143 Years: (As appears by Mr. *Norman's* Original Quantity $71^{\circ}. 30'$. compar'd with that now, $73^{\circ}. 45'$.) 'Tis certain that Charts made with these Lines of equal Dip upon them, will serve, at least in these Parts of the World, many Years, without any Necessity of Alteration, or any considerable Inconvenience to Navigation.

XII. If the Lines of equal Inclination or Dip below the Horizon, be drawn upon Maps and Charts, from good Observations, it will be very easy from the Longitude known, to find the Latitude; and from the Latitude known, to find the Longitude; and this both at Sea and Land.

Thus in that Sketch of a Map for some Parts of *England* and *Franco*, here exhibited, where I have either my self observed the Inclination of the Dipping Needle, or procur'd other Observations:

Suppose we are Travelling or Sailing along the Meridian of *London*, and we find the Angle of Dip, or Inclination to be 75° .

759. It is evident that this Meridian, and the Line of this Dip, can meet no where but in the Latitude of $53^{\circ} 31'$, which is therefore the *Latitude* sought. Or suppose we are Travelling or Sailing along the Parallel of *London*, i. e. in $51^{\circ} 32'$ North Latitude; and we find the Angle of Dip or Inclination to be 74° . This Parallel and the Line of this Dip, can meet no where but in $1^{\circ} 31'$ of *East* Longitude from *London*, which is therefore the *Longitude* sought. But this Scheme, and the larger Map hereto belonging, do make this Method so very easy, by bare Inspection, that I need say no more about it.

Corollary (1.) Hence we may correct all our Sea Charts, and Geographical Maps of Countries, and that to great Exactness; those of the Land especially; where there can be no Difficulty in making the nicest Observations.

Corollary (2.) Hence also, by the Help of a very few more good Observations, to be made at *Exeter*, *Carlisle*, the *Land's-End*, *Dublin*, *Parmouth*, *Paris*, *Edinburgh*, or the like convenient Places, we may soon draw the Lines of equal Dip on our Coasting Charts; which, used with a Dipping Needle of Four Feet long, will preserve the Ships near *Great Britain*.

Britain and Ireland; and particularly near *Scilly Islands*, from all Danger, for want of knowing their Longitude, or even their Latitude sometimes also. Which Thing I would therefore humbly recommend to the Right Honourable, and others the Commissioners appointed by Act of Parliament, for the Discovery of the Longitude, as the first Thing proper for their Consideration.

N. B. Though any good Needle, touched with any good Loadstone, will serve for the Purposes mentioned in this Paper; yet will it be very convenient, that at least those belonging to one Nation, should be made of the same Length, of Steel of the same Sort and Temper, and touch'd with the same Loadstone; (which ought to be the very best of its Kind in every Nation :) That so no manner of Irregularities may be so much as suspected in the Use of them; and that several Experiments may be better made by the Comparison of them, when used in several Parts of the World. It will also be very convenient that they be all so contriv'd, that they may be used either for Horizontal or Dipping Needles, upon all Occasions indifferently: That so the Knowledge of the true Inclination, by direct Observations in the Dipping Needle; and by Computations from the Vibrations of the Horizontal Needle, as above, may be the more Unexceptionable and Satisfactory.

N. B. That

N. B. That to avoid the shaking of the Ship at Sea, we must ever hang the Dipping Needle near the Center of Motion, & c. where the Mast cuts the Surface of the Water. We must also hang a great Weight under it, to keep it Steady and Perpendicular. If that be not sufficient, we must hang it on Two Circles, which turn on Axes at right Angles with each other; having a great Weight under them; as is done in other nice Cases at Sea. And if that be not sufficient, we must also set such Circles on a Frame, or Floor, which it self is placed within Two other like Circles, with their great Weight also. By which Means it will be possible, I believe, to try this Experiment almost as exactly at Sea, as at Land: Excepting perhaps the Case of a violent Storm: During which no one would chuse to make these Observations. Though it will be very proper, upon any Expectation of such a Storm, as well as immediately after it is over, to make them to the greatest Exactness possible.

Note, Lastly, That in all this Paper, wherever I compare Dipping Needles together, I suppose the Needles to be Similar in Bigness and Shape, equally Good, and touch'd with an equally Good Loadstone.

London, Nov. 20.

1719.

Will. Whiston:

1st T. 3. M.